Chapter 16 Conservation of Biodiversity in Managed Forests: Developing an Adaptive Decision Support System

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Abstract

Forest ecosystems provide several goods and services, but strategies for the conservation of biodiversity are missing in traditional forest management schemes. In this paper we develope a decision support system to optimize the conservation of biodiversity in managed forests, taking Dadia National Park as a case study area, a local Mediterranean hotspot of biodiversity in northeastern Greece. Using environmental niche factor analysis, we produced a series of spatially explicit habitat suitability models for vascular plants, amphibians, small birds and raptors and an overall model for total biodiversity. Further, we produced maps related to timber production and investigated potential conflicts between conservation of biodiversity and wood production. A decision support system based on a conflict assessment was created using three management scenarios. It enables the establishment of integrated management strategies and the assessment of their effects on biodiversity and timber production. Habitat suitability models for selected groups of organisms were found very effective to investigate the impact of the management on forests and wildlife. Further evaluation of key indicator taxa on these models could improve decision support systems and the sustainable management of forests.

Keywords

Forest ecology, sustainable use, timber extraction, habitat suitability,

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16.1 Introduction

The increasing exploitation of forests is one of the main reasons of human-induced loss of biodiversity (Lindenmayer et al. 2002; Foley et al. 2005). Although the socio-economic value of biodiversity was underestimated until recently (Costanza et al. 1997; Farber et al. 2002), its maintenance has become a commonly accepted goal of sustainable forestry (United Nations 1992; Kohm and Franklin 1997). The concept of ecosystem services provides a tool for communicating the importance of intact ecosystems for human well-being and a framework for the evaluation of multiple functions of landscapes and forests (Costanza et al. 1997; De Groot et al. 2002; Millennium Ecosystem Assessment 2005; Boyd and Banzhaf 2007; Steffan-Dewenter et al. 2007). In forest ecology, a major challenge is finding trade-offs between timber production and conservation of biodiversity (Johns 1997; Putz et al. 2001; Foley et al. 2005; Burke et al. 2008).

Forestry practices can enhance or reduce habitat for particular wildlife species by altering structural features at the stand scale (Burke et al. 2008; Rendón-Carmona et al. 2009). Forest management that enhances the heterogeneity of forests has in general a positive impact on the local biodiversity (Loehle et al. 2005; Gil-Tena et al. 2007; Torras et al. 2008; Kati et al. 2010; Poirazidis et al. 2010a; Schindler et at. 2010), but forest management guidelines for the maintenance of biodiversity are mainly valid for site specific conditions and can be rarely used as general directions (Loehle et al. 2005). As it is impossible to measure and monitor the effects of various management practices on the entire ecosystem, indicators are used as surrogates for biodiversity (Lindenmayer et al. 2000). Taxon-based proxies include flagship, umbrella and indicator species (Caro et al. 2004; Roberge and Angelstam 2004; Hess et al. 2006; Cabeza at el. 2008), while structure-based ones deal mainly with stand complexity, connectivity and heterogeneity (Lindenmayer et al. 2000; Schindler et al. 2008). Many researchers have explored the use of particular taxa, especially vascular plants, arthropods and birds, as surrogates for biodiversity, but a general pattern has not yet emerged (Kati et al. 2004b; Sauberer et al. 2004; Sergio et al. 2005; Billeter et al. 2008; Cabeza et al. 2008; Zografou et al. 2009). The importance of including several guilds of taxa to represent adequately overall biodiversity is currently stressed by several authors (Angelstam et al. 2004; Edenius and Milusinski 2006; Loehle et al. 2006).

In this study, we developed a decision support system with the ultimate goal of providing management guidelines and optimal solutions for the conservation of biodiversity in managed forests. We considered Dadia National Park,

a Mediterranean forest mosaic in north-eastern Greece, as a case study. Using available data sets from systematic scientific research in the area, a series of habitat suitability models for groups of indicator species and for overall biodiversity was produced to discover potential conflicts between biodiversity and timber production. Additionally, the effectiveness of different management scenarios was assessed.

16.2 Methods

The following method section contains information about the study area, the species data, and the applied statistical analyses. It further deals with the methods of producing maps of habitat suitability, timber standing volume, and forest management categories.

16.2.1 Study area

This research was conducted within Dadia National Park (hereafter called Dadia NP), a sub-mountainous area with a diverse landscape mosaic, dominated by extensive pine (*Pinus brutia, P. nigra*) and oak (*Quercus frainetto, Q. cerris, Q. pubescens*) forest, but containing also a variety of other habitats such as pastures, cultivated land, torrents and stony hills (Schindler et al. 2008; Poirazidis et al. 2010a). Dadia NP covers 43,000 ha in the prefecture of Evros, northeastern Greece (Fig. 16.1), and was designed to protect the diverse community of birds of prey, including the last breeding colony of the Eurasian black vulture (*Aegypius monachus*) in the Balkan peninsula (Poirazidis et al. 2004, 2010b; Skartsi et al. 2008). Almost 45% of the National Park is managed mainly for timber production (Zone B1), while it has been recognized during the last years that this specific zone is of great value for many species (Grill and Cleary 2003; Kati et al. 2004a, b, c, 2007; Korakis et al. 2006; Poirazidis et al. 2010a,b).

16.2.2 Species data

We used five datasets of indicator species groups as surrogates for the total biodiversity in Dadia NP, systematically surveyed using appropriate sampling techniques per group. Those comprised woody plants, non-woody vascular plants, amphibians, small birds and birds of prey (Kati and Sekercioglu 2006; Korakis et al. 2006; Poirazidis et al. 2009; Kret, Poirazidis, Kati, unpublished data). For each sampling plot (the number of plots was ranging from 34 to 63 depending on the indicator species group) all present species were evaluated.

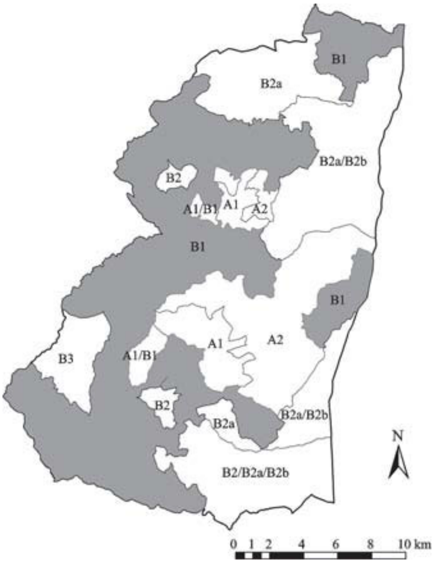

Fig. 16.1 Location and zoning of Dadia National Park, the case study area in north-eastern Greece. Zone B1 (highlighted in grey) represents the forest management area that was investigated in this study. A1, A2: strictly protected areas, B2: agroforestry area, B3: grazing land, A1/B1: forest management area that changed recently to strictly protected area.

The survey for vascular plants was based on fieldwork during the years 1999 and 2000, and the 62 sampling plots had been chosen in accordance to the survey for the Nature 2000 Network (Korakis et al. 2006). The sampling scheme for the amphibians was based on the breeding phenology of the species occurring in eastern Greece (Arnold 1978; Helmer and Scholte 1985), and each pond of the study area was visited once per month from February to July during the year 2007. The presence of amphibians was detected through a combination of visual encounter, aural and dip net surveys, during the diurnal transects in the banks of the ponds (Kret, Poirazidis, Kati, unpublished data). We excluded finally the species *Triturus cristatus* as its presence was verified at two sites, only. Similarly, a subset of the existing database for small birds (Kati and Sekercioglu 2006) was used for analysis. As the conservation value was one of the factors under evaluation, we included in our analysis only bird species that are "Species of European Conservation Concern" (SPEC; BirdLife International 2004). These included species with an unfavorable conservation status, concentrated in Europe (SPEC 2) or not (SPEC 3), as well as species with favorable conservation status, but concentrated in Europe (SPEC 4). Finally, for the small birds, the two species *Dendrocopos syriacus* and *D. medius* were used as a combined dataset due to limited detections of *D. medius*. The survey of birds of prey was based on a systematic monitoring of raptor territories that was conducted from 2001 through 2005 (Poirazidis et al. 2009,

2010b), and we pooled the data of all five years and plotted the centers of the yearly territories. The Black stork (*Ciconia nigra*), a species of conservation priority in the area (Tsachalidis and Poirazidis 2006), was included in the raptor dataset. A subset of the breeding raptor species was used in this study, and the criterion for selection was the relatively high abundance in order to produce stable habitat suitability models.

16.2.3 Habitat suitability maps and statistical analysis

Habitat suitability maps (HSM) have broad applicability within conservation biology and are of special interest to predict the distributions of wildlife species for geographical areas that have not been extensively surveyed. The methods for modeling habitat suitability can be classified into two groups: those requiring presence-only data and those requiring presence-absence data (Guisan and Zimmerman 2000). Here we prepare HSM using Ecological Niche Factor Analysis (ENFA) provided by the software BIOMAPPER (Hirzel et al. 2002). ENFA is a multivariate approach developed to predict habitat suitability based on the likelihood of occurrence of the species when absence data for the species are not available (Hirzel et al. 2002). Without absence data some limitations on the accuracy of the habitat suitability maps are possible (Hirzel and Le Lay 2008), and we reclassified the predictions into four robust levels (=bins) of suitability to settle this problem (Hirzel et al. 2006). The suitability is based on functions that define the marginality of the species, i.e. how the species mean differs from the mean of the entire area, and the specialization of the species, i.e. the ratio of the overall variance to the species variance. Marginality lies between 0 and 1, with larger values indicating that the focal species has habitat requirements that differ from the average available conditions. A high specialization value indicates that the focal species has a particular requirement for certain habitat characteristics and occupies a narrow range of variables compared to the overall range of variables within the study area (Hirzel et al. 2002).

We used 23 environmental variables, classified into four groups to derive potentially relevant predictors for species habitat selection (Table 16.1). This database contained maps stored in both a vectorial and a raster format. All species and habitat information was rasterized into a 50×50 m grid cell maps. Topographical data were directly obtained as quantitative variables. Variables quantifying land cover, landscape and potential sources of disturbance were transformed into frequency and distance variables. The forest cover categories were reclassified into pure broadleaves, mixed pine-oak and pure pine forest, but only the first two were used for the models, as the information from the third was redundant. As ENFA does not work with multinomial data, these qualitative maps were converted into several Boolean maps (i.e. one for each variable). Frequency describes the proportion of cells from a given category

within a circle around the focal cell and it was derived using a circular moving window. We varied the radius of the moving window to test the performance of three different scales (200 m, 500 m and 1,000 m), but finally only the scale of 1,000 m was used as it performed better than the others. The topographical descriptors were averaged by means of a similar radius circular moving window. Spatial data analysis was conducted using ArcMap 9.0 and the Spatial Analyst extension.

Correlations between all variables of the initial pool of predictors (Table 16.1) were calculated prior to the ENFA. When two or more predictors had a correlation coefficient greater than 0.7, only the most proximal was kept (Austin 2002). Topographic and frequency environmental layers were normalized using the "box–cox" algorithm (Sokal and Rohlf 1981) and distance variables by the "square root" algorithm. There are different algorithms available in BIOMAPPER to build habitat suitability maps by ENFA (Hirzel et al. 2002) and following Hirzel and Arlettaz (2003) we used the geometric mean

Table 16.1 Environmental variables used in ENFA as predictors to define the species' ecological niche.

Environmental predictors	Scales (m)
Topography	-
1. Altitude	200, 500, 1000
2. 1 SD of altitude	200, 500, 1000
3. Slope	200, 500, 1000
4. Northness aspect	200, 500, 1000
Landscape/Forest attributes	-
5. Relative richness index	200, 500, 1000
6. Fragmentation index	200, 500, 1000
7. Frequency of broadleaves	200, 500, 1000
8. Frequency of mixed forest (Pine-Oak)	200, 500, 1000
Other ecological metrics	-
9. Frequency of openings	200, 500, 1000
10. Frequency of agricultural lands	200, 500, 1000
11. Frequency of permanent water	200, 500, 1000
12. Frequency of rocky area	200, 500, 1000
13. Distance to openings	-
14. Distance to agricultural lands	-
15. Distance to main river	-
16. Distance to permanent water	-
17. Distance to rocky area	-
Potential disturbance metrics	-
18. Frequency of paved roads	200, 500, 1000
19. Frequency of unpaved roads	200, 500, 1000
20. Frequency of urban area	200, 500, 1000
21. Distance to paved roads	-
22. Distance to unpaved roads	-
23. Distance to urban area	-

algorithm to account for the density of the observations in environmental space.

For the plants, the number of species was used as dependent variable per plot and we created two multiple regression models (one for woody plants and one for non-woody vascular plants) to predict species richness. The resulting models were transformed with the "box-Cox byte" algorithm and combined with equal weight (factor 0.5) to produce the overall "plant HSM". For each of the three groups of fauna, an overall HSM was created combining the specific HSMs by user-defined weight per species (Eastman 2001), which depended on the conservation value (Appendix). Finally, all HSMs per organism group were combined into an overall biodiversity HSM applying a new user-defined weight per group. The HSM for breeding Black vulture and Egyptian vulture (*Neophron percnopterus*) – the species with the highest conservation value in the area – were not included in the initial raptor HSM, but were used as Boolean data in a later step (see below) to highlight the priority areas for conservation of these two species.

16.2.4 Timber standing volume

We used the recent forest inventory for wood production of the local Forest Service (2006-2016) to produce quantitative maps of the distribution of standing wood volumes (basal area) (Consorzio Forestale del Ticino 2006). We used the stand level as spatial unit to summarize these data (417 sub-units of the division of managed forest, with an average size of 46.5 ± 18.9 ha). The timber volume was described as pine, oak and total volume (Consorzio Forestale del Ticino 2006). We used only the managed area of Dadia NP (zone B1), excluding the non-managed strictly protected areas (Fig. 16.1).

16.2.5 Establishment of the management scenarios

To obtain spatially explicit management plans at stand level, we reclassified the biodiversity thematic maps into four bins representing habitat suitability: (1) unsuitable, (2) marginal, (3) suitable and (4) optimal. We also reclassified the timber maps into four bins representing the standing volume: (1) minimum, (2) medium, (3) large and (4) maximum. We used the Natural Break method (ArcMap) for the biodiversity bin classification, and the four timber volume bins were defined by values of total standing timber volume of <500 m^3, 500-1,000 m^3, 1,000-2,000 m^3 and >2,000 m^3 per stand. We finally considered four possible general management actions at the stand level, in order to integrate biodiversity values into the timber management: (1) management without limitations (*free forestry*), (2) management with tem-

poral restrictions, (3) management with temporal and spatial restrictions, and (4) management focussing on the ecological values (*ecological management*).

In this study, we implemented three management scenarios. The "*biodiversity scenario*" focused on the maximization of the biodiversity value (maximum environmental profit) in the managed forest. It was defined by the biodiversity models with each bin of habitat suitability leading to related management actions (Table 16.2), e.g. biodiversity bin 1 *"unsuitable"* leading to management action 1 *"free forestry"* and biodiversity bin 4 *"optimal"* to management action 4 *"ecological management"*. The "*timber scenario*" focused on the maximization of the economical benefits for the timber production (maximum economical profit) and was defined by the standing volume map with each bin of timber density leading to inverse related management actions (Table 16.2), e.g. timber volume bin 1 "*minimal"* leading to management action 4 "*ecological management"* or timber volume bin 4 *"maximum"* to management action 1 *"management without limitations"*. The third scenario was the "*trade off scenario*", which attempted to maximize the long-term net benefits for both biodiversity and society. The established trade off matrix considered both biodiversity and timber production at the same level, leading to the final determination of the management action for each stand (Table 16.2).

Table 16.2 Forest management categories determined by biodiversity and timber production under the scenarios *biodiversity*, *timber* and *trade off*.

Scenario		Biodiversity				Timber				Trade Off			
Timber bins		**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Biodiversity bins	**1**	FF	FF	FF	FF	EM	TSR	TR	FF	FF	FF	FF	FF
	2	TR	TR	TR	TR	EM	TSR	TR	FF	TR	TR	FF	FF
	3	TSR	TSR	TSR	TSR	EM	TSR	TR	FF	TSR	TSR	TR	TR
	4	EM	EM	EM	EM	EM	TSR	TR	FF	EM	EM	TSR	TSR

FF: free forestry, TR: temporal restrictions, TSR: temporal and spatial restrictions, EM: ecological management. Biodiversity bins: 1 unsuitable, 2 marginal, 3 suitable, 4 optimal; timber bins: 1 minimal, 2 medium, 3 large, 4 maximal.

We applied each scenario to each biodiversity data set as well as to the overall biodiversity HSM. For each scenario at the last step, we used the suitable and optimal areas for Eurasian black vulture and Egyptian vulture as Boolean variables as such: suitable and optimal areas for Eurasian black vulture were upgraded to the Management action "4" (ecological management) and for Egyptian vulture to the Management action "3" (temporal and spatial restrictions).

16.3 Results

In the following section, we present the resulting maps regarding habitat suitability, timber standing volume, and forest management categories. We further present the evaluation of the effectiveness of the different management

scenarios in conserving biodiversity.

16.3.1 Habitat suitability maps

The species richness of vascular plants (351 plant species in 63 plots) was modeled using the eco-geographical variables as independent variables. The resulting regression model for woody plants was "Y = 4.3 + 2.01 northness – 10.29 frequency of openings + 2.53 frequency of mixed forest + 0.001 frequency of rocks + 0.001 distance to agricultural lands", while for non-woody plants it was "Y = 30.4 + 0.24 slope – 0.23 relative richness index + 5.02 frequency of mixed forest". Both models were significant at the level p=0.05 and were combined equally to the overall HSM for plants (Fig. 16.2a)

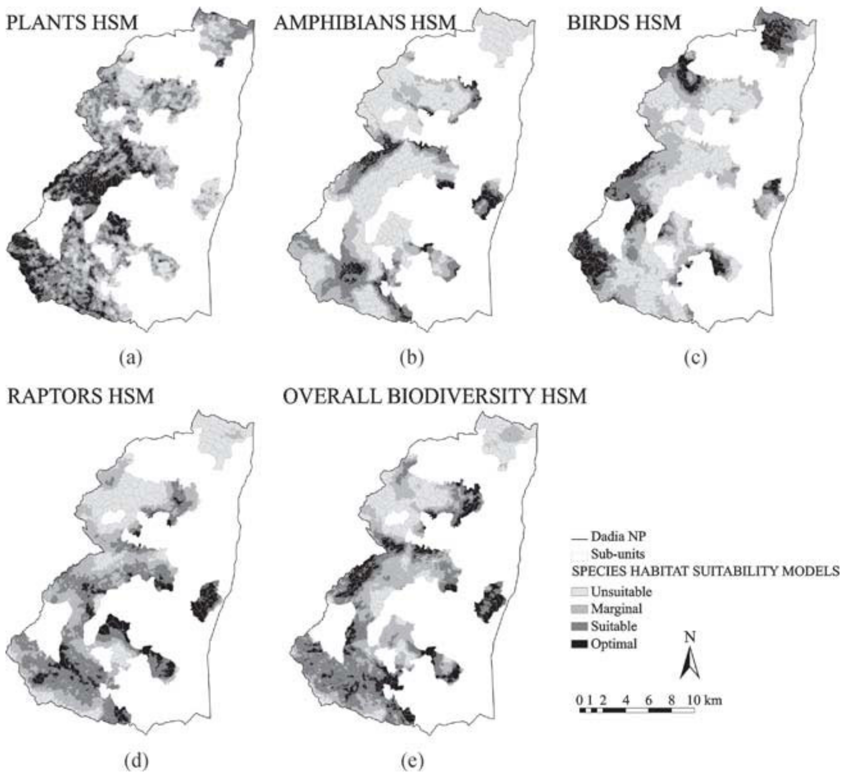

Fig. 16.2 Habitat suitability maps for (a) plants, (b) amphibians, (c) small birds, (d) raptors and (e) overall biodiversity in Dadia NP.

Amphibians (10 species in 53 plots) showed a pronounced specialization for certain habitats as their mean global marginality was 0.94 (range 0.63-1.35) and their specialization was 4.37 (range 1.59-12.56). Both groups, small birds

and raptors, showed intermediate sensibility and differentiation of habitat use. The mean global marginality of small birds was 0.70 (range 0.35-1.05) and the specialization was 3.23 (range 1.13-6.93). For the raptor HSM, ten species of breeding raptors plus the Black stork had a relative abundance that enabled stable models. The mean global marginality for raptors was 0.63 (range 0.17-1.64) and the specialization was 2.05 (range 1.03-6.05). Finally, separate HSM were created for each taxon-group of animals (Fig. 16.2b,c,d) using species specific weights (Appendix). The combined overall biodiversity HSM resulted (Fig. 16.2e), applying the weights of 0.5 to raptors HSM, 0.25 to amphibians HSM, 0.15 to small birds HSM, and 0.1 to plants HSM.

16.3.2 Standing volume distribution maps

The mean pine wood volume was 1,533.2 $m^3 \pm$ 1,424.1 (sd) per stand, with a maximum value of 7,380.8 m^3 while the mean oak wood volume was 731.5 $\pm$ 658.1 m^3 with a maximum value of 4,785.3 m^3. The total timber volume ranged from 69 to 8,094 m^3 (Fig. 16.3), while the total volume per ha was 49.2 $m^3 \pm$ 26.2 and ranged per forest stand from 2 m^3/ha to 131 m^3/ha.

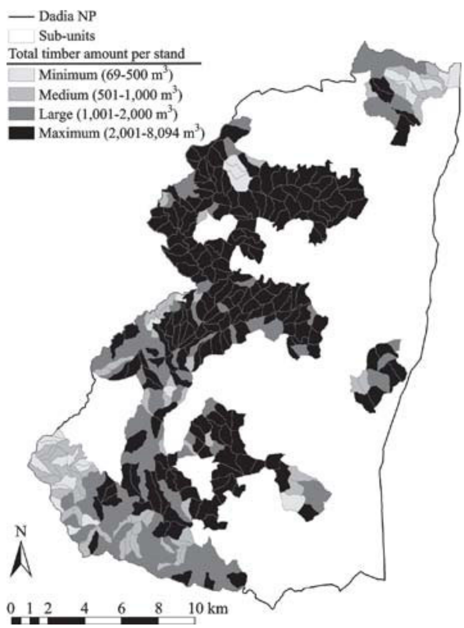

Fig. 16.3 Total timber standing volume of the managed forest area in Dadia NP.

16.3.3 Establishment of the management scenarios

We produced three thematic maps of spatially explicit management plans, based on the desired forestry policy in the management area (Fig. 16.4). At the timber scenario, where conservation priorities are considered exclusively in areas without economical value for timber, only 6% of the area was proposed for ecological management and 46% for free forestry. On the other hand, in the biodiversity scenario, where the most suitable areas remain unexploited, 18% of the managed forests were proposed for ecological management and

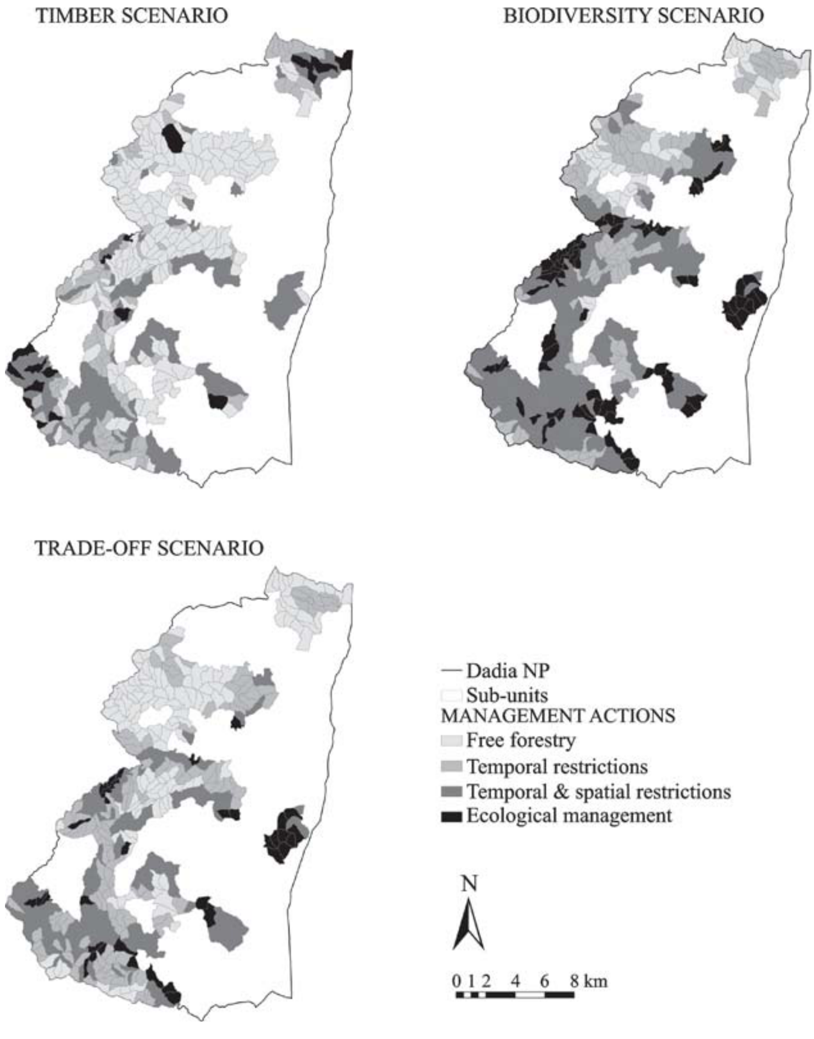

Fig. 16.4 Spatial forest management plans, presenting the distribution of the four forest management categories under the timber, trade off and biodiversity scenario.

11% for free forestry. The trade off scenario, taking into account both timber and biodiversity, lies in between, proposing 9% of the area for ecological management and 32% for free forestry.

The trade off scenario served both ecosystem services, biodiversity values and timber production (Fig. 16.5). In this scenario, 91% of the area with low suitability for biodiversity (*bins unsuitable and marginal*) was covered by the management category "free forestry", while the areas of high suitability for biodiversity (*bins suitable and optimal*) were intensively covered by the management categories "temporal and spatial restrictions" (47%) and "ecological management" (25%). For comparison, in the timber scenario, only 60% of the low biodiversity area was dedicated to free forestry and more importantly only 42% and 4% of the high biodiversity areas were classified as "temporal and spatial restrictions" and "ecological management", respectively (Fig. 16.5).

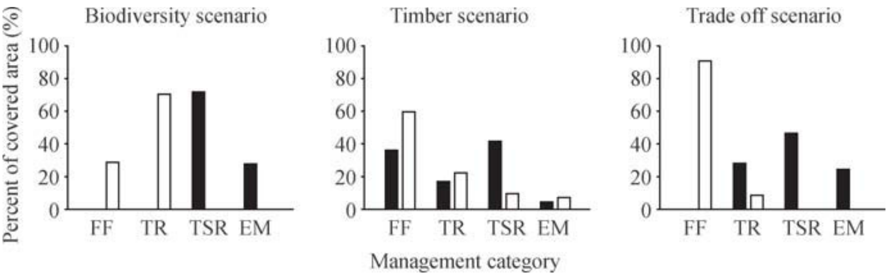

Fig. 16.5 Management and conservation of areas of differing suitability of biodiversity under the scenarios "Biodiversity", "Trade off", and "Timber". Black bars: forest stands of high suitability for biodiversity (bins suitable and optimal), white bars: forest stands of low suitability for biodiversity (bins unsuitable and marginal); FF: free forestry, TR: temporal restrictions, TSR: temporal and spatial restrictions, EM: ecological management.

16.4 Discussion

In the following section we discuss the need of integrating biodiversity into forest management, and several aspects regarding multi-taxa indicators, decision support systems, and the scenarios applied in this study.

16.4.1 Integrating biodiversity into forest management

New environmental policies call for increased attention to biodiversity issues in forest management planning, given that the loss and fragmentation of mature forest together with the structural diversity decline have threatened forest-

dependent species (Andrén 1994; Siitonen 2001; Thompson et al. 2003; Angelstam et al. 2004; Poirazidis et al. 2004). Sustainable forestry and deadwood supply have recently emerged as two of the twenty-six headline indicators towards halting further biodiversity loss in Europe (European Environmental Agency 2007). In this frame, the approach developed in this study provides a useful tool for forest managers. We established biodiversity priority areas into the managed areas, providing a guideline for effective management strategies. We also developed habitat suitability models based on environmental features and we identified habitat associations that provide an important source of information for general habitat management issues. These models quantifying relationships between species and their habitats are considered nowadays one of the most efficient tools for forest management (Edenuis and Mikusinsky 2006). Sustainable forest management should be efficient, satisfying on one hand conservation goals while minimizing on the other hand socio-economic costs and the area removed from timber production (Pressey et al. 1997; Montigny and McLean 2005).

16.4.2 Species selection and multi-taxa indicator species

We modeled in this research habitat suitability for several groups of organisms, using totally 351 taxa of vascular plants, 10 species of amphibians and 23 species of birds for the assessment. For a successful use of habitat suitability models in forest biodiversity management an appropriate selection of species is required and multi-taxa bio-indication has several advantages (King et al. 1998; Angelstam et al. 2004; Rempel et al. 2004; Wrbka et al. 2008). Ecologically different taxa can show different patterns of biodiversity and it is assumed that even several species of one single taxon or guild are not enough for being representative (Schulze et al. 2004; Billeter et al. 2008; Cabeza et al. 2008). Also Edenius and Mikuszinski (2006) stressed the need for multi-species selection procedures in their recent review on the use of HSM in forest management. They have found only one study (out of 55 reviewed ones) that followed a multi-taxa approach, and only five papers of the review (9%) could be attributed to indicator species in the species selection procedure.

The indicator species approach has been criticized on conceptual grounds, such that no species share the same ecological niche, as well as on empirical grounds, i.e. untested or unverified relationships between the indicator and the species or species groups that the indicator supposedly covers (Lindenmayer et al. 2000; Rempel et al. 2004; Roberge and Angelstam 2004; Edenius and Mikuszinski 2006). In our study we used vascular plants, amphibians, small birds and raptors as indicator groups in habitat suitability models. Recent research confirmed that plants and birds are well performing surrogate taxa for overall biodiversity in Dadia NP (Kati et al. 2004b; see also Sauberer et al. 2004 for a Central European case study). Amphibians, due to their very spe-

cific habitat needs and life cycle, are important for being complementary and good indicators of habitat matrix permeability (Ray et al. 2002; Kati et al. 2004a, 2007; Cabeza et al. 2008). Raptors are top predators; requiring enough prey, large areas and limited disturbance, they indicate ecosystem health and perform well as indicators of biodiversity (Sergio et al. 2005; Sekercioglu 2006; but see also Cabeza et al. 2008). Raptors are also focal species of conservation efforts in the reserve, as their populations in Dadia NP are of regional importance (Poirazidis et al. 2004, 2007, 2010b; Skartsi et al. 2008).

16.4.3 Decision Support Systems and comparison of scenarios

Concerning limited funding and limited data sources, adaptive management is a useful tool for fast implementations (Angelstam et al. 2004; Duff et al. 2009). Ideally, an active adaptive management approach with iterated assessment and corrective action should be applied through continuous mutual learning by scientists, policymakers, managers and other actors until the targets are reached (Simberloff 1999; Brown et al. 2001; Angelstam et al. 2004; Steffan-Dewenter et al. 2007; Duff et al. 2009). The three scenarios, presented in this case study, are adaptive in terms of their main objectives and regarding their simplicity. The timber scenario is a simple approach to integrate conservation of biodiversity into forest management when timber production has the main priority. In this scenario more restrictive conservation management will be done only in forest stands with little timber. The biodiversity scenario can be followed when conservation is the key issue. Restrictions are proposed, where habitat suitability reaches maximum values, the performance regarding conservation is optimal, but the socio-economic benefits remain totally unused in forest stands with a high level of biodiversity. The trade off scenario as an alternative solution proved very useful to integrate timber extraction and nature conservation and an optimization of the benefits for society and biodiversity could be achieved. Compared with the timber scenario, free forestry is encouraged where habitat suitability is lower but forest stands of high biodiversity have more restrictions. A decision support system can be an effective mechanism to support technological and managerial decision making (Malczewski 2006) as it can combine multiple sources of information (models and data) into a single system that provides a tool to manipulate the information. With these capabilities, it supports decision makers in cognitive tasks that involve choices, judgment and decisions, in recognizing needs and identifying objectives, as well as in formulating and evaluating different courses of action (Garcia and Armbruster 1997). In the case of sustainable forest management, these actions are forest management scenarios, i.e. collections of rules and strategies regarding harvest scheduling and forest regeneration (Van Damme et al. 2003).

Timber harvesting and conservation of biodiversity are not necessarily

mutually exclusive and some rules of temporal and spatial restrictions can optimize their coexistence (Lõhmus 2005; Brown et al. 2007). Integrating different data sources to a decision support system for spatial forest management planning can increase clearly the sustainability of forest management. Viable populations of indicators species and a high level of biodiversity can be maintained, without losing the socio-economic benefits of professional timber production. At the local scale, a selective targeting approach that identifies forest stands of potential high biodiversity and nature conservation value is essential. Once identified, these areas can be highlighted for inclusion in future local targets and management prescriptions altered accordingly (Bayliss et al. 2005). As maps of habitat suitability were initially created for individual species, our approach provides also a further resource for species specific conservation management. We recommend applying habitat suitability modeling to selected groups of indicator organisms to develop spatial management plans for managed forests. This enhances the sustainability of the management and promotes monitoring and evaluation of its effects on wildlife. The inclusion of further taxa as indicators of overall biodiversity into the existing decision support system is a prerequisite for continuous improvements of a sustainable forest management.

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Appendix

Selected species used for the habitat suitability models for amphibians, small birds and raptors, and user-defined weights (adding up to the value of 1 per group). SPEC values for avian "Species of European Conservation Concern" (BirdLife International 2004): 2- "concentrated in Europe and with an unfavorable conservation status"; 3- "not concentrated in Europe, but with an unfavorable conservation status"; 4- "concentrated in Europe, but with a favorable conservation status".

For the list of the 351 plant species, used for this analysis see Korakis et al. (2006), available by the authors.

Species	-	SPEC	Weight factor
Amphibians	**-**	**-**	**-**
Fire Salamander	*Salamandra salamandra*	-	0.2
Yellow-bellied Toad	*Bombina variegata*	-	0.15
Common Toad	*Bufo bufo*	-	0.1
European Green Toad	*Bufo viridis*	-	0.1
Common Spadefoot	*Pelobates fuscus*	-	0.1
Smooth Newt	*Triturus vulgaris*	-	0.1
European Tree Frog	*Hyla arborea*	-	0.1
Marsh Frog	*Rana ridibunda*	-	0.05
Balkan Stream Frog	*Rana graeca*	-	0.05
Agile Frog	*Rana dalmatina*	-	0.05
Small birds	**-**	**-**	**-**
Woodchat Shrike	*Lanius senator*	2	0.1
Ortolan Bunting	*Emberiza hortulana*	2	0.1
Black-headed Bunting	*Emberiza melanocephala*	2	0.1
Woodlark	*Lullula arborea*	2	0.1
Corn Bunting	*Milandra calandra*	2	0.1
Bonelli's Warbler	*Phylloscopus bonelli*	2	0.1
Green Woodpecker	*Picus viridis*	2	0.1
Olivaceous Warbler	*Hippolais pallida*	3	0.05
European Bee-eater	*Merops apiaster*	3	0.05
Orphean Warbler	*Sylvia hortensis*	3	0.05
Red-backed Shrike	*Lanius collurio*	3	0.05
Middle Spotted Woodpecker	*Dendrocopos medius*	4	0.05
Syrian Woodpecker	*Dendrocopos syriacus*	4	0.05
Raptors	**-**	**-**	**-**
Eurasian Black Vulture	*Aegypius monachus*	1	Special category
Egyptian Vulture	*Neophron percnopterus*	3	Special category
Golden Eagle	*Aquila chrysaetos*	3	0.3
Lesser Spotted Eagle	*Aquila pomarina*	2	0.2
Booted Eagle	*Hierraetus pennatus*	3	0.2
Black Stork	*Ciconia nigra*	2	0.1
Short-toed Eagle	*Circaetus gallicus*	3	0.1
Goshawk	*Accipiter gentilis*	-	0.05
Honey Buzzard	*Pernis apivorus*	-	0.03
Common Buzzard	*Buteo buteo*	-	0.01
Sparrowhawk	*Accipiter nisus*	-	0.01